DOCUMENT RESUME

ED 083 674 EA 005 510

TITLE	Cost and Energy Savings Opportunities with Heating, Air Conditioning and Lighting Systems in Schools.
INSTITUTION	Electric Energy Association, New York, N.Y.
PUB DATE	73
NOTE	12p.
AVAILABLE FROM	Electric Energy Association, 90 Park Avenue, New York, New York 10016 (Single copies free, multiple copies $.65 each)
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	*Air Conditioning; Check Lists; Conservation (Concept); *Cost Effectiveness; Educational Facilities; *Energy; *Heating; *Lighting; School Improvement

ABSTRACT

Great potential exists for saving energy and operating costs with a wide variety of heat conservation systems. Two major electric services--space conditioning and lighting--afford cost and energy savings opportunities. These services are detailed in checklist fashion in this brochure, with the suggestions included under space conditioning generally applicable to all type of systems--electric, gas, or oil. Electric space conditioning and lighting concepts are reviewed, with discussions being pertinent to new construction and modernization activities. (Photographs may reproduce poorly.) (Author/MLF)

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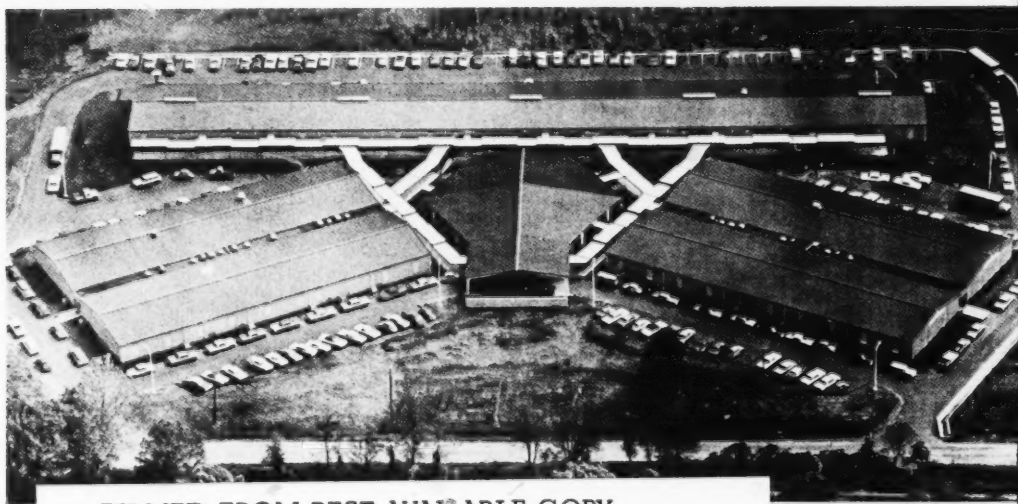
cost and energy savings opportunities with heating, air conditioning and lighting systems in schools



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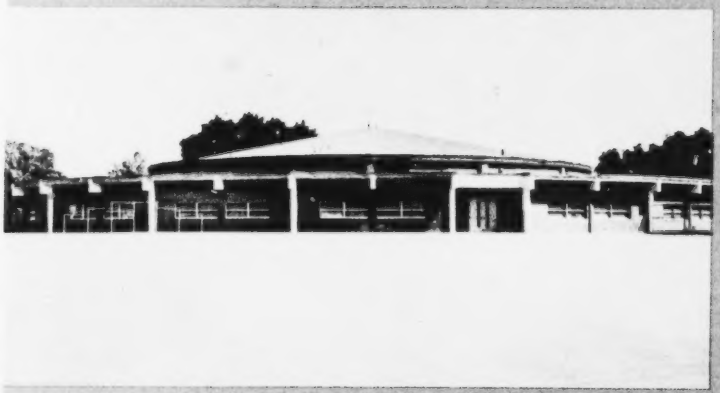
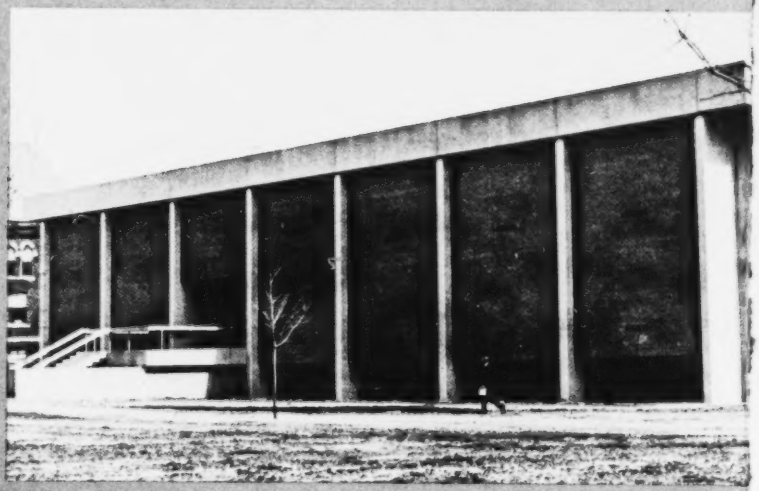
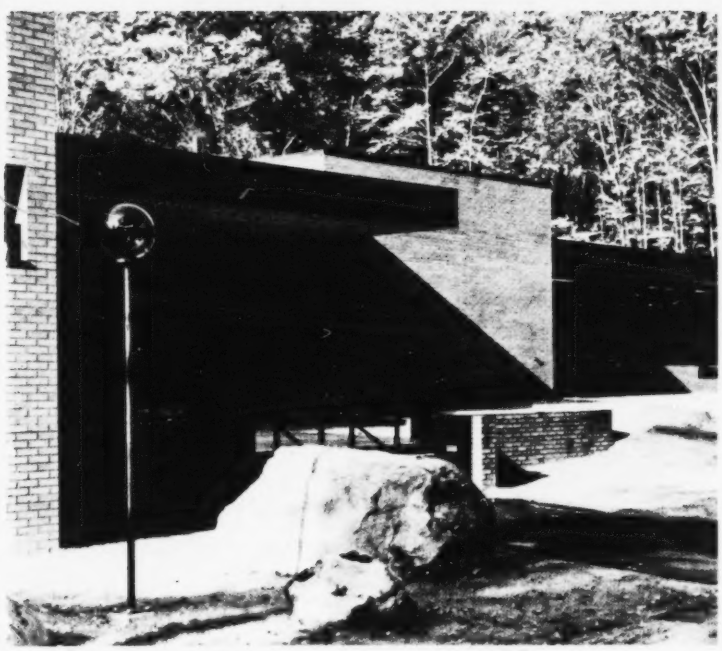




introduction

As its title suggests, this publication is designed to assist school officials in saving both money and energy in the construction and operation of their buildings. While the task of minimizing expenditures has long been a concern of school administrators, the need for energy conservation is relatively new and is receiving increasing attention in all quarters of our society.

Two major electric services—space conditioning and lighting—afford cost and energy savings opportunities. These are detailed in check-list fashion in the first section of this brochure. The suggestions included under space conditioning generally apply to all types of systems: electric, gas or oil. Many of the suggestions for space conditioning and lighting practices are part of routine operating procedures in every well managed school facility. They are presented to focus school management's attention on the savings potential of frequently taken-for-granted operating expenses. In the second section of this publication, electric space conditioning and lighting concepts are reviewed. These discussions are pertinent to new construction and modernization activities.



Great potential exists for saving energy and operating costs with a wide variety of heat conservation systems. School designers—architects and consulting engineers—will be familiar with these systems. They are described here, in generally nontechnical language, to acquaint school officials with them.

There is a present and important need to conserve all forms of energy. However, even in an era of abundant energy, the operating practices and system concepts presented in this brochure will have merit.

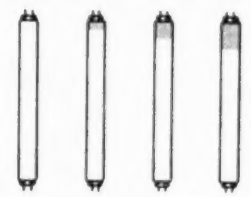
energy conserving considerations

Conserving energy and reducing operating expenses in any school require attention to structural detail as well as planning, cost/benefit analyses and programs for ensuring that recommended operating procedures are carried out. Application of the suggestions listed below can produce significant reductions in energy use and operating expense.

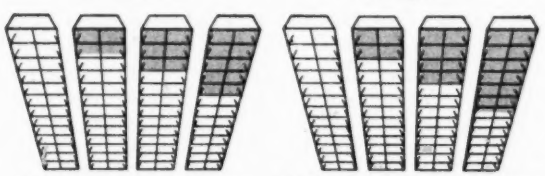
heating, ventilating and air conditioning

- ☐ Schedule careful annual inspections of all caulking, weatherstripping and other building sealants. Air leakage through such barriers can boost heating energy requirements by 15 to 30 percent.
- ☐ Retain an engineer or contractor to check the effectiveness of the insulation in walls, floors and roofs. Thickness alone isn't a reliable measure of effectiveness. If more insulation is advisable, don't skimp; it pays off handsomely. Specify insulating glass.
- ☐ Have vestibule doors or special wind stops installed to reduce the heat losses associated with normal use of exterior doors.
- ☐ Establish, to the extent feasible, separate temperature control zones that can be heated or cooled independently.
- ☐ Investigate the merit of installing a programmed automatic climate control system. Make provision for selective manual override so that areas can be conditioned for such off-hour functions as meetings, adult classes and sporting events.
- ☐ Interconnect the light and ventilator switches of individually ventilated rooms to avoid expelling conditioned air unnecessarily from rooms not in use.
- ☐ Stagger early morning warm-up periods of independent temperature control zones to minimize demand.
- ☐ Shut off comfort conditioning in unoccupied rooms, zones or buildings after hours and during weekends, vacations and holidays.
- ☐ Establish a routine of reducing thermostat settings in areas that will be unoccupied for significant spans of time.
- ☐ Draw drapes, blinds and window shades on overcast days during the winter and at night to cut heat losses. Similar action will cut the cooling load on hot, bright summer days.
- ☐ Establish careful administrative control to make sure that exterior doors and windows are closed and that system controls are set properly and in working order.
- ☐ Avoid setting thermostats to a level higher than desired room temperature. Overheating, which can result, is wasteful of energy and increases operating costs.
- ☐ Discourage chronic resetting of room thermostats. Once set to comfortable levels, they should be left alone, except for setback situations. If necessary, install thermostats that can't be adjusted without a key.
- ☐ Clean filter systems regularly to assure adequate air circulation with minimum fan horsepower.
- ☐ Shut down ventilation systems when rooms or zones are unoccupied. Otherwise, conditioned air will be wastefully exhausted.
- ☐ Minimize ventilation air to the extent consistent with health, comfort and code requirements.
- ☐ Keep all outside air dampers closed while the building is unoccupied.
- ☐ Verify periodically that air distribution throughout the building is balanced and that all equipment is functioning normally.
- ☐ Take advantage of energy conservation advice from your local utility, manufacturers, architects, consulting engineers and builders.

"Natural" Lamp Depreciation



Dust and Dirt **Total Light Loss**



lighting

- ☐ Replace, where appropriate, incandescent area lighting with more efficient sources, such as fluorescent, mercury and metal-halide lamps. (Incandescent bulbs are still preferred for some applications, however.)
- ☐ Apply light finishes to walls, ceilings, floors and furnishings.
- ☐ Install new lighting equipment with special lenses, polarizers and beam distribution devices that utilize energy more efficiently.
- ☐ Encourage staff and students to turn off lights when a room will be unoccupied for 15 minutes or more.
- ☐ Utilize natural light where practical but control glare and reflections.
- ☐ Clean lighting fixtures thoroughly at least once a year. Under average conditions classroom fixtures will collect enough dirt to cause light output to decline at least two percent a month. Dirt and normal deterioration together can cut light output more than 50 percent in two years.
- ☐ Wash walls and ceilings periodically and repaint as necessary. (Dingy surfaces do not reflect as much light as bright, clean ones.)
- ☐ Require periodic tests with a lightmeter to monitor the rate at which light output is deteriorating. These tests should be part of the preventive maintenance program.
- ☐ Replace lamps on a group basis at regular intervals instead of waiting for individual units to fail.
- ☐ Ask the designer or supplier of the lighting system to recommend a lighting maintenance program.
- ☐ Post instructions for proper lighting system operating, cleaning and maintenance procedures, and audit compliance by the custodial staff.

electric space conditioning concepts

An important aspect of prudent energy use and operating cost control in schools is the recovery of heat, where possible. The ventilation requirements of schools can be responsible for substantial energy losses. Air that has been heated or cooled, then exhausted to the outdoors, must be replaced by outside air which in turn has to be heated or cooled to bring it to proper temperature and humidity. Energy is expended at every step in the process.

In addition, lights and occupants are sources of major quantities of heat in most school buildings, and the disposition or utilization of this heat is a basic consideration in energy consumption.

Fortunately, various heat transfer techniques and devices are now available that permit the automatic and economic recovery and reuse of this otherwise wasted heat. Brief discussions of such systems follow.

refrigeration-type heat recovery

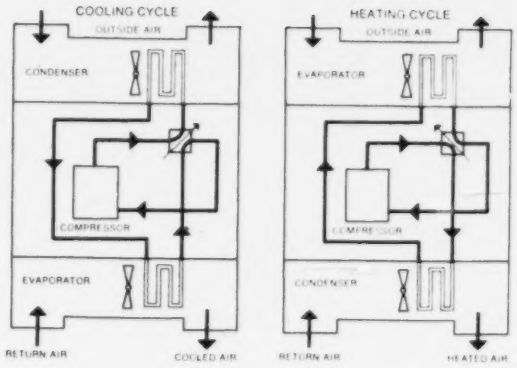
These systems have the ability to transfer internal heat from one zone where it is in excess to another that requires it, thereby optimizing energy use.

Of the several refrigeration-type heat recovery systems, those employing heat pumps deserve special consideration because this remarkable machine has the unique ability to furnish two or three times more energy in the form of heat than is put into it in the form of electric power. This is so because it removes and uses heat from other sources. In a basic air-to-air heat pump this source is outside air which contains heat even on very cold days; or the heat source could be water in which case water-to-air heat pumps would be used.

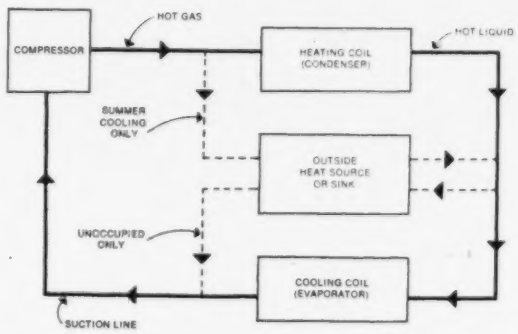
Air-source heat pump transfer systems can transfer internal heat when it is available, and also resort to outside air as a source when there is no surplus internal heat. The diagram shows an air-to-air heat pump applied as a heat recovery machine in a double-duct system capable of simultaneous heating and cooling.

Water-source heat pump transfer systems are designed specifically for optimizing energy use in multiple-zone structures. While the system has some of the characteristics of a decentralized system with independent in-zone heating/cooling units, it also requires some remote equipment common to all the zones. The choice of temperature in each zone is completely independent regardless of the season or mode of operation in other spaces.

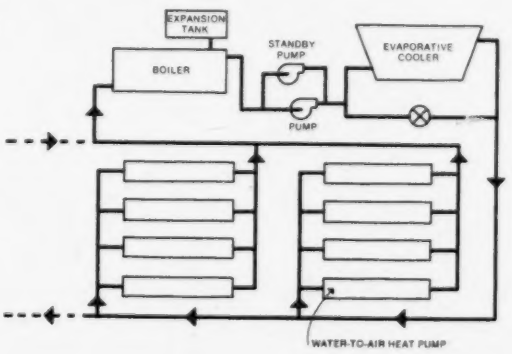
Other refrigeration-type heat recovery systems utilize such elements as chillers and double-bundle condensers. Some systems have the capability of storing excess heat for use when needed.



Heat pump



Air-source heat pump transfer system



Water-source heat pump transfer system

exhaust air heat recovery

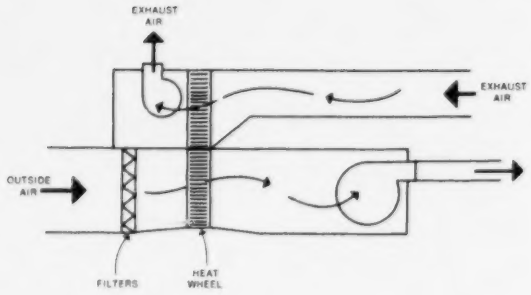
There are decided economic and energy conservation advantages to be realized by providing some means for reclaiming the conditioning effect of exhaust air. Methods for doing so include the devices described below.

Heat wheels are motor-driven disks of heat-absorbing material. Installed in the ductwork, they rotate athwart the flow of air in the ducts continuously picking up heat from the outbound air and releasing it to the inbound air, or vice versa.

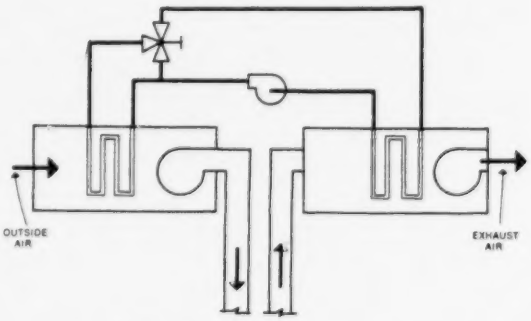
Runaround systems employ a pair of heat exchangers connected to one another by a closed loop of pipe carrying a liquid solution. One of the heat exchangers is installed in the exhaust air duct where it is warmed or cooled by the air about to be expelled to the atmosphere. The other is placed in the inlet duct where the direction of the heat transfer is reversed.

Air-to-air heat exchangers are basically open-ended metal boxes divided into myriad narrow passages. The exhaust air and makeup air ducts are attached to this box in such a way that the two streams of air flow through it in opposite directions. Heat energy is transferred from the warmer air stream to the cooler air stream by conduction through walls of adjacent air passages.

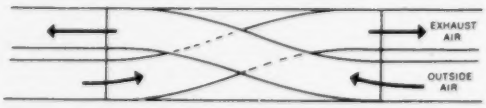
Heat pipes essentially are short lengths of copper tubing sealed at both ends and containing a refrigerant. Banks of these devices installed with one end in the exhaust duct and the other in the makeup air duct continuously transfer heat from one duct to the other.



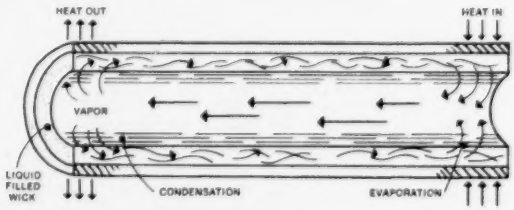
Heat wheel



Runaround system



Air-to-air heat exchanger



Heat pipe

electric space conditioning concepts cont.

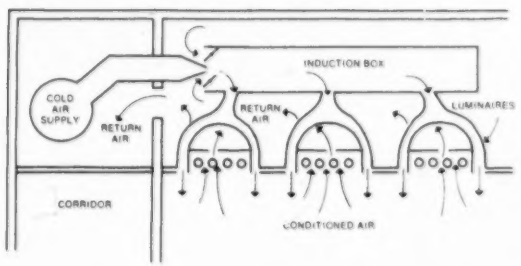
recovering lighting heat

Ducted air systems can be designed to provide a direct means of controlling and redistributing the heat generated by lighting fixtures. Air drawn into a ceiling plenum after it passes over the lamps and sheet metal of a luminaire picks up as much as 80 percent of the heat. Despite various losses, 50 to 65 percent of the lamp heat is retained in the plenum and can be put to use in the space conditioning system if it is needed, or vented to the outside if it is not. Plenums for this purpose can be designed into new schools or provided in older schools between the original high ceiling and a new suspended one.

The diagram shows a portion of a single-duct heat recovery system as it might be installed in a school building that requires simultaneous wintertime heating and cooling—a common situation in many parts of the country. A key element in this system is the air-mixing box with thermostatically controlled dampers. When full cooling is required, 100 percent cold primary air is delivered to the space. When warmer air is indicated, warm air from the ceiling cavity is mixed with a correspondingly smaller amount of primary air.

The plenum air may also be used for heating portions of the building, although it will normally have to be supplemented by heating units. **The use of air return fixtures can be beneficial in the summer also, because lighting heat can be drawn off and vented to the outside, thereby reducing the cooling load on the school's air conditioning system.** An alternate system using water-cooled fixtures provides these same benefits, and when combined with a heat recovery system the heat gathered may be used elsewhere in the structure in a variety of ways.

Recovering the excess heat from lighting fixtures offers an energy conservation bonus: the cooler operating temperature of the lights causes them to burn more efficiently. Lamps produce as much as 13 percent more illumination for a given level of electric energy input when they are cooled.



lighting concepts

Lighting theory and practice have undergone significant change in recent years. This is particularly true with respect to schools. Architects and design engineers no longer think of lighting as a separate element, but rather as an integral part of the modern learning environment. Schools designed on the open plan and those with movable partitions present special lighting design problems. Fresh ideas and concepts are being proposed and accepted at a rapid rate and new technological developments are keeping pace.

Natural light was long considered to be the most desirable, and the school's artificial lighting system merely supplemental. Today there is growing recognition that natural light coming into the classroom has disadvantages, including inconsistency, glare and induced heat. In winter heat loss through the glass represents wasted energy as well.

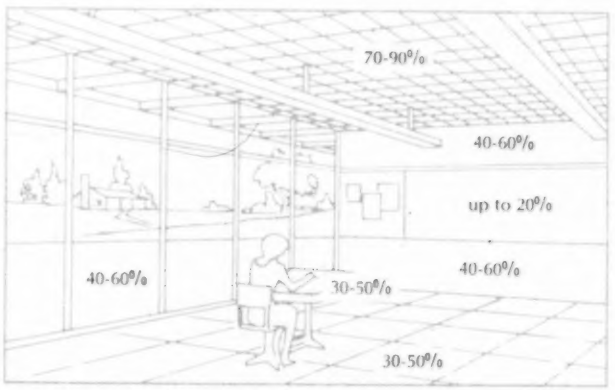
Similarly, metal-halide lamps, which are more efficient than conventional mercury vapor lamps and often can operate in the same fixtures, are now available. The high pressure sodium lamp, most efficient of all, is of particular value for outdoor security lighting.

Other improvements such as U-shaped fluorescent lamps, lamps with shielded cathodes and prismatic fixtures are also available.

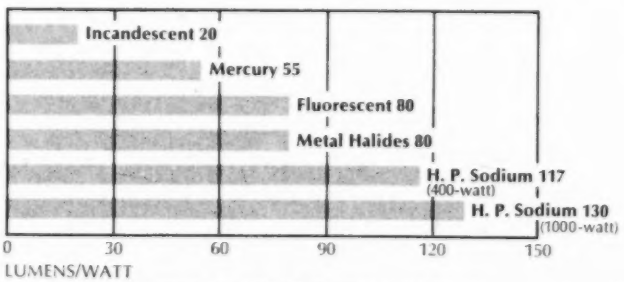
Designers choosing from among these new sources and fixtures, must, however, bear in mind that the most efficient lighting option may not always be the best or the most comfortable for the specific task at hand. One aspect of school lighting that is changing is the relative emphasis placed on footcandle levels, as such. Today, such other factors as veiling reflections, contrast rendition and discomfort glare are increasingly being taken into account. Accordingly, lighting system specialists now use the concepts Visual Comfort Probability, which takes into account the subjective reactions of people to glare; and Equivalent Sphere Illumination, which indicates how effective the lighting system is in providing required task visibility.

A substantial amount of the light on a student's work surface arrives indirectly, by reflection or re-reflection from ceilings, walls, table or desk tops, and floors. If such surfaces are dark, they absorb most of the light striking them. On the other hand light-colored surfaces can reduce room lighting requirements by as much as 15 percent.

Improved light sources provide a wider range of choices, are more efficient and afford much greater value for a given investment. For example, a fluorescent system is more efficient than an incandescent system, producing several times more light for a given amount of energy consumed. Mercury vapor lighting, also very efficient, is gaining acceptance for gymnasiums, swimming pools and other high-ceilinged areas, partly because of its efficiency but also because of its long life.



Recommended Reflectances in the Classroom (I.E.S.)



Approximate Comparative Light Output of Light Sources

modernization or expansion of school facilities

Consultation with design professionals can make a big difference in the effectiveness of a modernization program because of the complex interrelation between the existing structure, planned use of space, and the space conditioning and lighting systems.

When such a program involves replacement or upgrading of space conditioning and lighting systems, the ideas presented earlier in this publication should be thoroughly considered. Here are additional suggestions which may help to conserve costs, energy and space in modernization programs.

existing central hydronic (water or steam) system

When the existing boiler requires replacement, an electric boiler should be considered. Where structural additions or alterations have rendered the capacity of the existing central boiler marginal, supplementary individual electric boilers might be added, each located conveniently near the area it serves. This arrangement shortens distribution lines, minimizes standby losses and permits individually controlled zones.

When the existing piping network is sound and cooling is to be supplied, electric water-to-air heat pumps might be chosen. In this way, the heating function of the boiler being replaced can be partially taken over by the heat pumps, which also provide cooling.

existing central ducted air system

The existing furnace can be directly replaced with an electric furnace, or when cooling is required, a heat pump. Alternatively, new or existing air handling units can be equipped with electric strip heaters. Another option is to install electric duct heaters directly in the ducts leading from either a new or the existing air handler. Such heaters installed in the primary air handling duct function much like an electric furnace, but when they are installed in several branch ducts, they afford individual temperature control in each of the zones served by the branch ducts. This arrangement allows for economy in heating spaces with only periodic use.

existing decentralized or in-space system

A high degree of installation and operating flexibility can be achieved with electric in-space heating, ventilating and air conditioning systems. Instead of moving heated or cooled water or air from a central point through pipes or ducts to where it is needed, these systems generate or reject heat right in the space being conditioned. Zones of any size, even single rooms, can be updated independently without affecting the balance of the building, and each space can be separately controlled. In classrooms, individual through-the-wall unit ventilators heat, cool and ventilate. In corridors and other areas not requiring ventilation, wall, ceiling or baseboard units can be installed as circumstances dictate.

relighting possibilities

New or variable use of space will affect the performance of an existing lighting system. Where tasks are known to be at fixed locations, recommended lighting levels need be achieved only at the task, and general lighting may be reduced.

Conversion to use of more efficient fixtures and sources can produce real improvement in lighting quality at the same or reduced expenditure of energy. The reflectivity of the various surfaces in each space should, of course, be considered when selecting colors and textures and in the lighting design.

Where ceiling height permits, a new integrated ceiling system can be installed at a lower level, and the resulting space utilized as a plenum for air handling. Modern ceiling systems frequently feature a heat recovery capability.